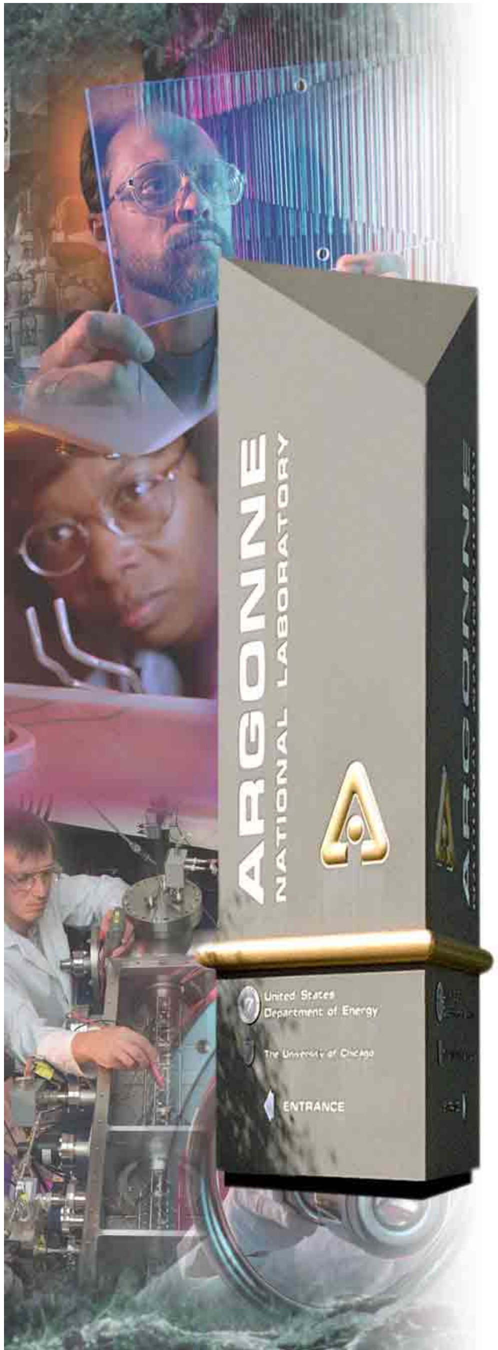


Development and Validation of an Advanced Multiphase Glass Furnace Model

Presenter: Brian Golchert – ANL

Argonne National Laboratory

Office of Science
U.S. Department of Energy

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

Presentation Outline

- **Program Overview**
  - Goals, Technical Approach, Program Description
  - Program Status
    - *Program ‘completed’ on 12/31/03 as scheduled*
- **Technical Progress/Accomplishments**
  - Brief Overview of Program Accomplishments
  - Continued application of GFM to industrial furnaces
- **Technology Transfer of GFM Code to Industry**
  - Initiated in FY04
  - Initial Technology Transfer Results
- **Broadened the ‘Vision’ of GFM**

Program Overview

and

Status

Program Goals

- Advance the "State of the Art" in Glass Furnace Modeling/Simulation
- Provide Industry with a Validated Furnace Model that Can be used to Analyze Different Types of Furnaces
- Create a Code that can be Used by Engineers, not Only Computational Experts
- Make the Validated Code (Executable and Source Codes) Readily Available to Industrial Users.

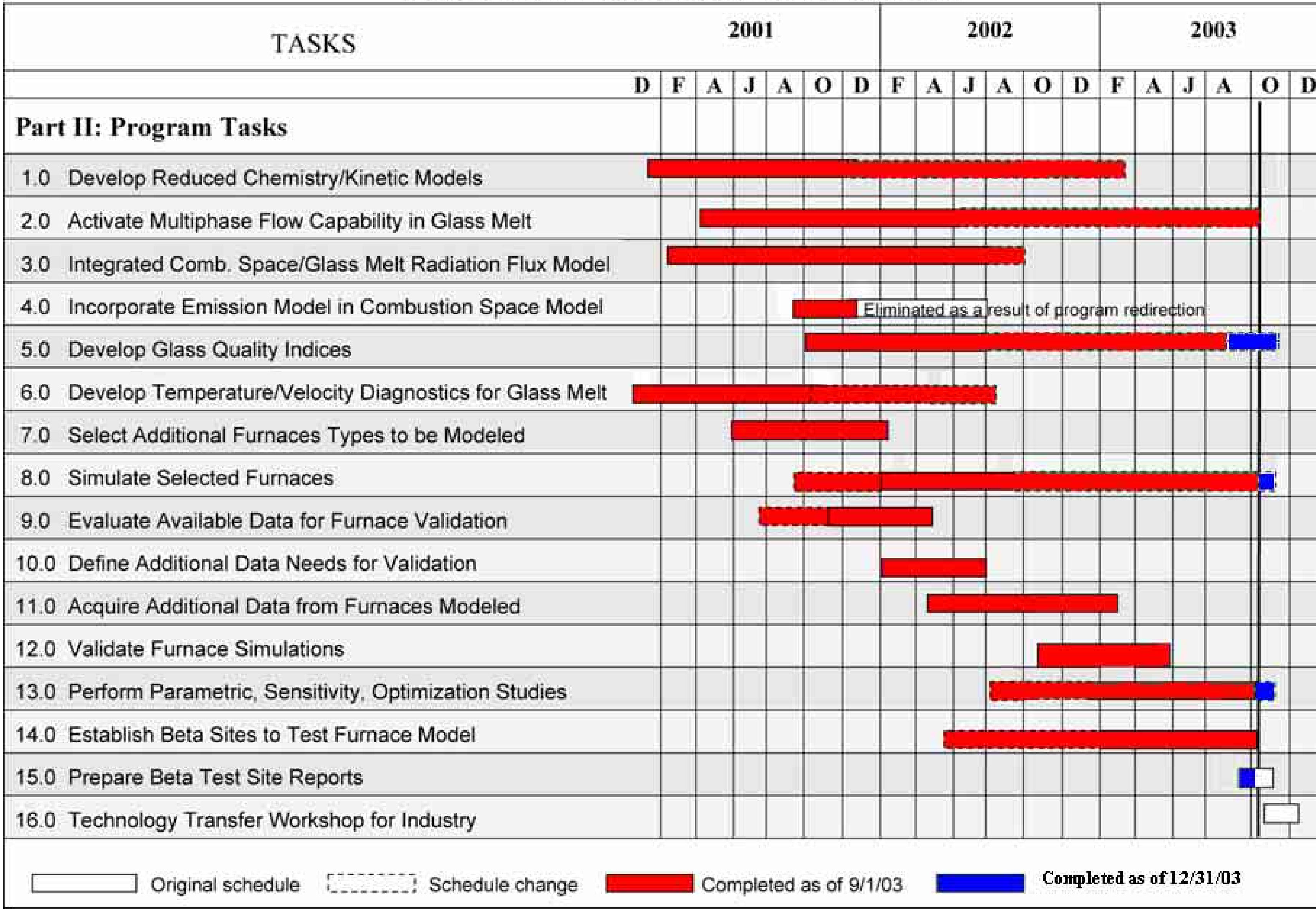
Program Description

- **Two Part Program Initiated in 1998**
- **Supported by Industrial Consortium**
  - Techneglas, Inc. Libbey, Inc. Visteon
  - Owens Corning Osram Sylvania
- **University Participants**
  - Purdue University Mississippi State University
- **Five-Year Program Schedule**
  - Part I Program completed
  - Part II Program completed at end of CY 03
- **Deliverable: User Friendly, Validated, Glass Furnace Model for Use by Engineers**
  - A step change in modeling capability
  - Technical Support is Being Provided via a Follow-On Tech Transfer Program

Technical Approach for Achieving Program Goals

- **ANL's Multiphase Reacting Flow CFD Codes (ICOMFLO, ICRKFLO) used to Develop a Coupled Glass Furnace Model (GFM)**
  - Incorporated advanced phenomenological models for spectral radiation heat transfer, batch melting, foam layer formation, etc.
- **Construct Simulations of Selected Furnaces**
- **Develop/Install Diagnostics in Selected (3) Furnaces to Acquire Data for Code Validation**
- **Validate Furnace Models with Data Acquired**
- **Demonstrate the Utility and Benefits That Can Be Derived From the Use of GFM Code**
  - Conduct extensive parametric, sensitivity and optimization studies to identify opportunities to improve furnace performance

PROGRAM WBS AND SCHEDULE



Technical Progress

and

Accomplishments

Accomplishments During Program

- **Developed a Coupled Glass Furnace Model (GFM)**
  - Incorporated advanced phenomenological models for spectral radiation heat transfer, batch melting, pollutant formation, etc.
- **Initial Workshop Held at OSU to Introduce GFM to the Industry**
  - Demo code given to 32 attendees
- **Code Validation Data Obtained from Three Furnaces with Different Operation and Design Characteristics**
  - Cross fired oxy-fuel furnace, a regenerative end port fired furnace, and a recuperative fiberglass furnace
- **Advanced Version of GFM 2.0 Developed and Validated with in situ Data from Three Furnaces**
  - Robust pre and post-processor
  - Spectral radiation computed throughout furnace volume

Accomplishments During Program (cont'd)

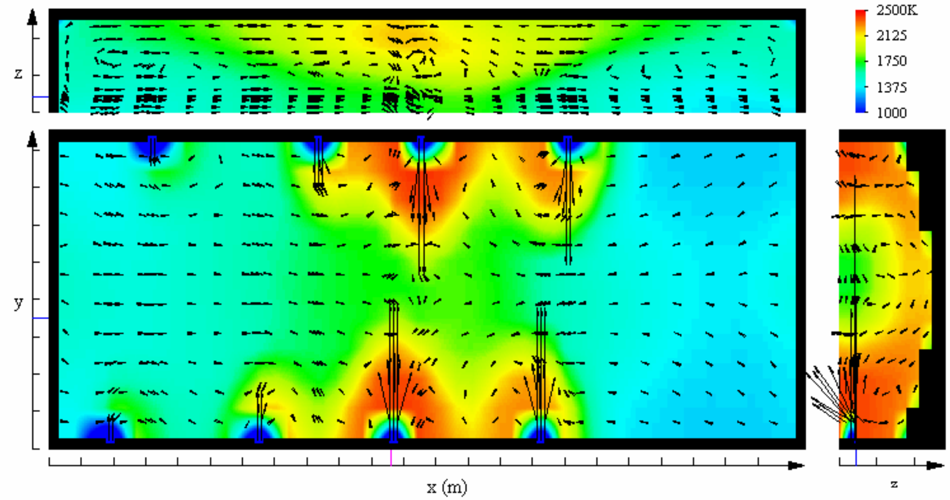
- **GFM 2.0 Beta Tested by Industrial Participants (IP)**
- **IP's Built Simulations and Used Them to Conduct Parametric, Sensitivity, & Optimization Studies**
  - Parameters varied specified by IPs
  - Studies conducted jointly by IPs and ANL
- **Multiphase Analytical Capabilities of GFM 3.0 (Final Version of Code)**
  - Transport and reaction of solid, gas, and liquid species is computed throughout glass melt
  - Chemical reactions in melt and batch incorporated
  - Foam formation/thickness calculated
  - Quality indices incorporated
  - Gas release from melt to combustion space
  - GFM3.0 to be released to licensees of GFM2.0

Continued Application of GFM by Industry

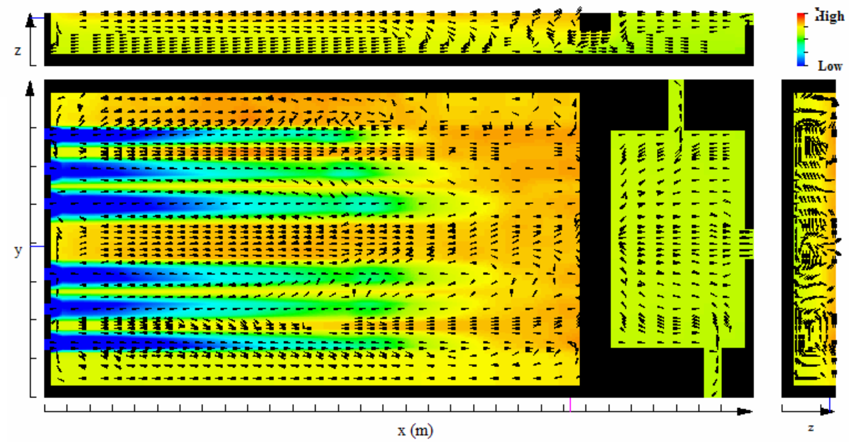
- **A Techneglas melter developed an operational problem as a result of an obstruction that led to a significant decrease in quality thus causing the operators to reduce the pull**

- **Parametric studies were/are being conducted to help:**
  - Identify the cause of the reduction in quality
  - Determination if operational parameters can be adjusted to allow increasing the pull without sacrificing quality

Computational Results



Combustion Space

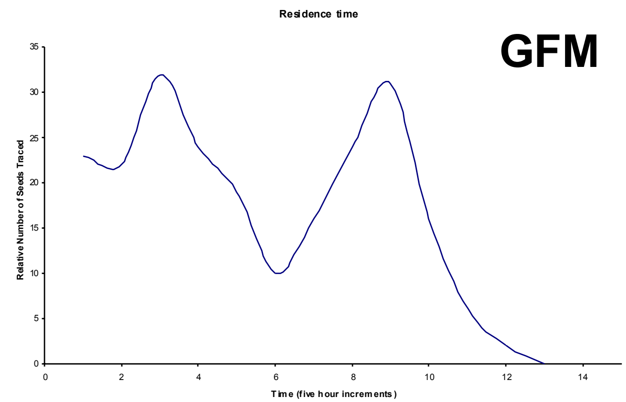


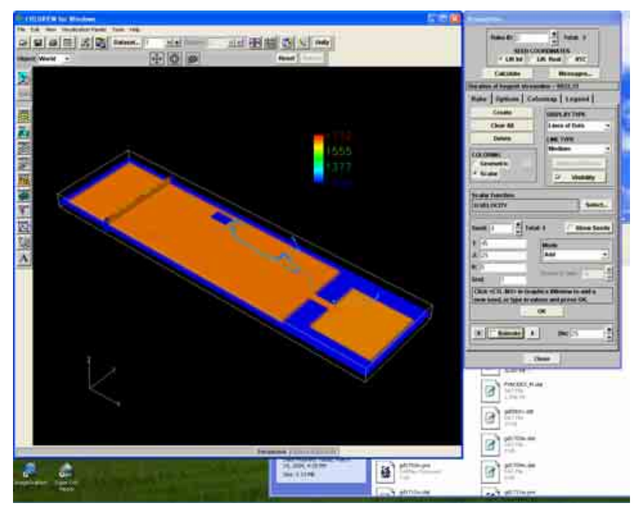
MELT

Quality Issues in Techneglas Furnace

- **Two methods are available to investigate quality issues with the GFM**
  - ‘Traditional’ quality indices as an output of the GFM
  - Particle tracing through a commercial visualization code FIELDVIEW
- **‘Traditional’ residence time quality indices indicate a bi-model distribution**
  - Shows possible reason for quality problems. Shortest residence time in the region of the obstruction

GFM

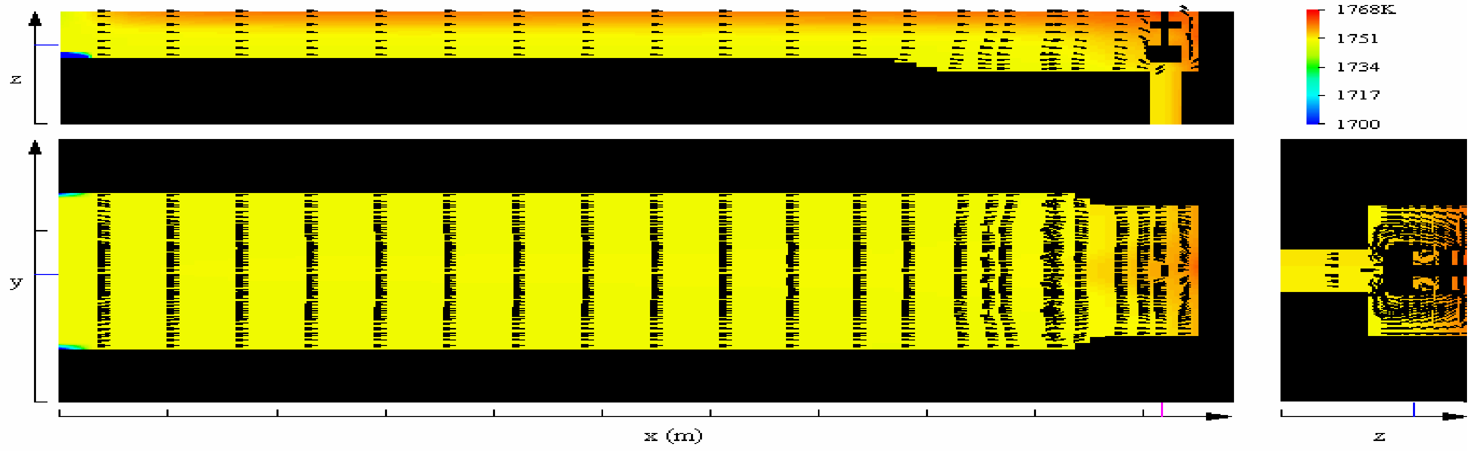




Fieldview

Techneglas Furnace Forehearth

- John Chumley of Techneglas has extended the model for the melt and the combustion space to model the Pittston B forehearth
- Preliminary melt calculations are shown below.



The Glass Furnace Model Technology Transfer (GFM-TT) Program

GFM-Technical Transfer Objective

- **Disseminate and Promote Widespread Use of the GFM Code Throughout the Glass Industry**

The GFM-TT Objective Will be Achieved By

- **Widely Disseminating Information on GFM Code to Industry**
  - Collaborating with GMIC
  - Brochure developed describing code capabilities and availability
    - *Broad mailing by GMIC to Industry*
- **Making GFM Code Readily Available to Interested Users**
  - Free trial license available for six to nine month period
- **Providing Technical Support for the GFM Code Users during the Free Trial Period**
- **Promoting Development and Implementation of Long Term Technical Support Mechanism for the GFM Code User**

Dissemination of Information on the GFM Code and Response from Industry

- **A Brochure has been prepared and sent to over 90 glass company contacts. This brochure describes:**
  - Code and its capabilities
  - How interested users can license code
  - How technical support will be provided
  - Availability of a **FREE trial license!**
- **Brochure Mailing Handled by GMIC**
  - Cover letter urges interested users to obtain a trial license
- **A Follow-up Electronic Mailing was Made Last Week**

Mechanism for Licensing GFM Code to Interested Users

- **GFM2.0 Code is available at the ANL Software Shop**
  - Accessible via internet htttp://softwareshop.anl.gov/
  - Site maintained by ANL Office of Technology Transfer
    - *Handles all licensing for ANL*
  - Allows interested users opportunity to license code online
  - Terms, conditions, and procedures for licensing code clearly outlined
- **After receiving trial license, user contacts ANL to arrange for free training on the use of the code**
  - Training is usually done during one afternoon and the following morning
  - Begin working with ANL staff on your furnace of interest and learn how to use the code at the same time
- **At the end of the free trial period, users will be required to pay a ONE TIME nominal licensing fee to continue using the code**

Technical Transfer Status as of 16 June 2004

- **Six Trial Licenses have been Signed**
  - PPG (2)
  - St. Gobain
  - Guardian
  - St. George Crystal
  - Anchor Hocking Glass
- **Additional companies have indicated they will likely apply for trial licenses**
- **Training has been conducted for three licensees**

Mechanism for Providing Technical Support to GFM Code Users

- **An Attempt will be made to Establish a GFM Code User Group (CUG)**
  - Each licensee will automatically become a member
  - Each member entitled to technical support services
- **Technical Support Services That Will Be Available to CUG Members**
  - Individual instruction on use of code at ANL
    - *Expect average user will require 2 days*
    - *User will create and run furnace simulations*
  - Additional support provided on an as needed basis
    - *Hours available will depend on number of users (CUG members)*
    - *Estimated minimum of 40 hours/year*
  - Customization services will be provided within allowable hour limits
    - *Modification of code when applied to unique/unusual geometries*
    - *Source code expected to evolve & be improved*
- **Ideally, the CUG Members will be Issued Improved Versions of GFM as the Code Evolves**
- **Technical Support will be Provided at No Cost Over 6-9 Month Period**
  - Levels to be compatible with resources provided by DOE

Long Term Technical Support

- **Need and Mechanism for Continuing Support to Be Determined by CUG Membership**
  - At conclusion of 9 month DOE Support Period

- **CUG Would Ideally Evolve into an Industry Organization that**
  - Supports continued development/improvement of the GFM codes
    - *Funding provided by membership dues and possibly DOE*
  - Ensures that technical support for the GFM is available
  - Continues to maintain a “state of the art” modeling capability for the industry

Going beyond the original frontier…..

Expanded 'Vision' for the Glass Furnace Model

- **GFM can be the 'repository' of many of the advances achieved in the DOE Glass projects such as**
  - Alfred's material property database
  - Sandia's crown corrosion work
  - BOC's batch preheat work
- **Incorporation of the results from these projects into the GFM achieves the following:**
  - Enhanced modeling capabilities
  - Creates a commercialization vehicle for these DOE projects
  - Increased likelihood that the results from all of these projects will culminate in energy savings to the industry

Center for Glass Research Database

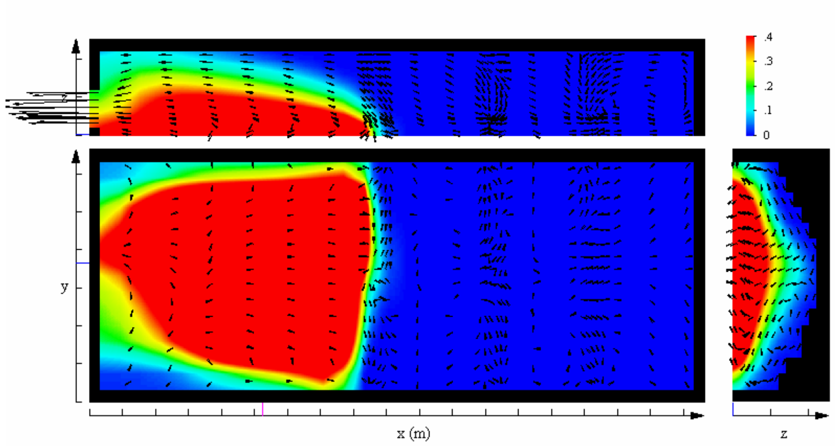
- **A significant effort has been expended by the DOE and by Alfred University (CGR) to develop a high temperature materials database specifically for computational modeling**
- **CGR has completed their database and it covers the majority of glasses found in industry**
- **CGR, ANL, and DOE are discussing the incorporation of the CGR database into the GFM. This would allow the user to ‘point and click’ on a particular glass composition in order to obtain the required thermophysical properties needed**
  - Using the database in the GFM would provide the user ready access to hard-to-find thermophysical data

Corrosion Modeling in Glass Furnaces

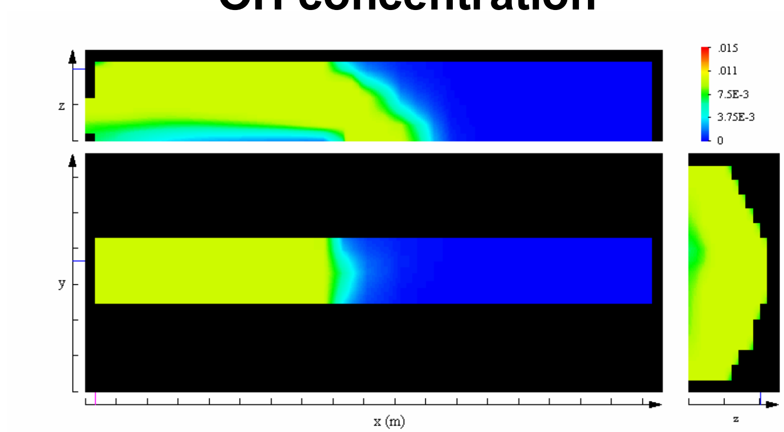
- **The DOE funded Sandia project on crown corrosion has developed models and chemical reactions to determine the likely locations of corrosion based on species concentration and temperature**
  - All variables available from the GFM calculations

- **Based on observations in furnaces and the results from several modeling efforts, a crude, first order corrosion model in the melt has been developed.**

Implementing Sandia's Model into the GFM



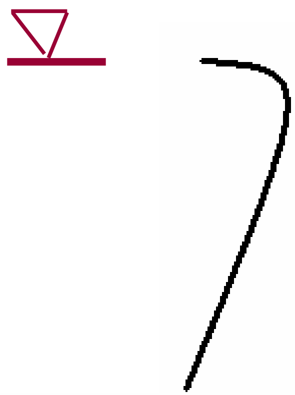
OH concentration



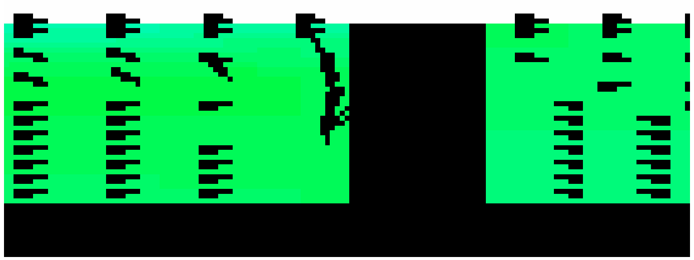
Estimate of corrosion

- **The Sandia model indicates that the OH concentration and the temperature are key components to crown corrosion**
- **A crude model similar to Sandia's model has been incorporated into the GFM**
- **Gaseous OH from the batch reactions is transported throughout the combustion space**
- **OH concentration and wall temperature give indications of locations of high crown corrosion**

Using Results from GFM to 'Predict' Corrosion/Erosion in the Melt Refractory



Approximate wear shape in melter back wall



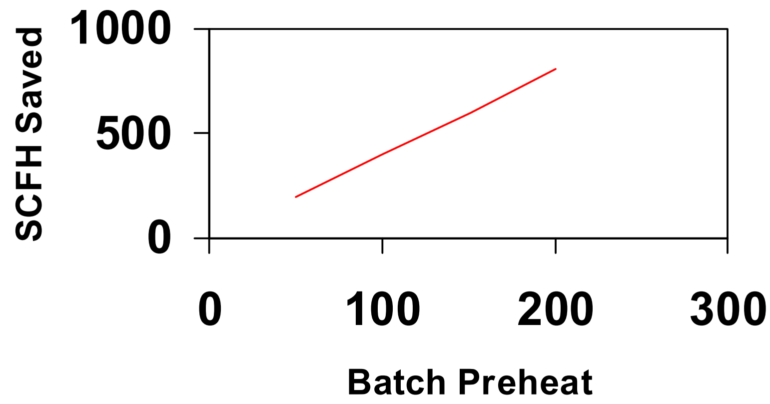
Computed velocity field near back wall

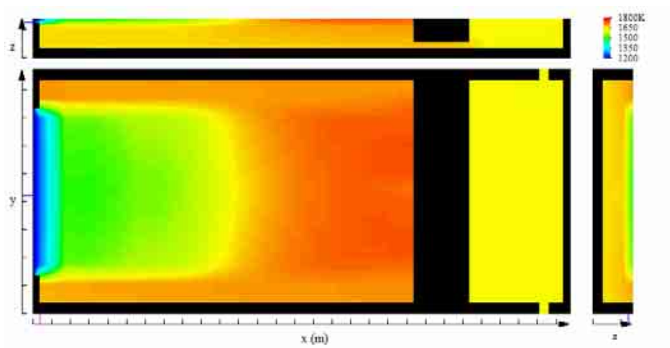
- After several visits and talks with plant personnel, it became apparent that there was a relationship between liquid glass velocity and corrosion/erosion of refractory material.
- The computed velocity field is in very good agreement with the observed wear pattern
- GFM can be used to estimate locations of high refractory wear caused by high melt velocities

Effect of Batch Pre-heating

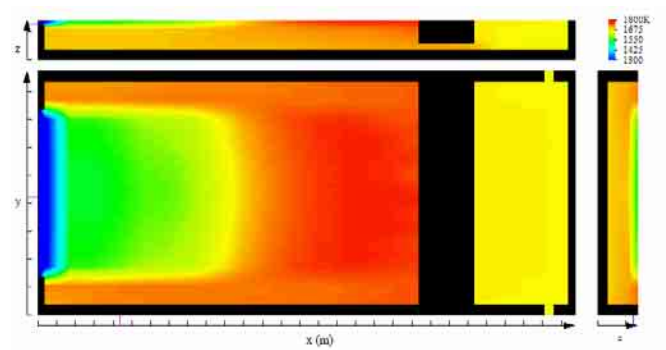
- The DOE funded a program to investigate the effects of pre-heating the batch using the exhaust heat from the combustion space
- The GFM can model the effects of batch pre-heating on the temperature and flow field in the melter.

Savings = 4 SCFH/kg/ C





Base Case



Batch Pre-heat (+100 C)

Additional Work Needed for Batch Pre-Heating

- **There are two main components for modeling batch preheating**
  - Thermal effects (easy)
  - Gas release effects
- **Thermal effects of batch preheating already in the GFM**
- **Work is being done to incorporate the effect of preheating on the gas release using models/data derived by Purdue University.**